Digital Simulcast

Outline

- Strategy
- Digital RF Transmission
- Data Compression
- Discussion

Strategy

Political Situation in the U.S.

- The FCC plays a key role in establishing U.S. video standards
- The FCC has advocated a simulcast approach for HDTV, in a single 6 MHz channel
- The FCC will make no decision on EDTV until it has a decision on HDTV
- It is highly desirable for every broadcaster to be able to obtain a simulcast HDTV channel
- Is this an excuse to select the Zenith system?
- In the long term, we believe that all-digital HDTV is the right approach. We must find a solution which accomodates terrestrial broadcast

Technical Challenges

- **Design a digital transmission system for terrestrial broadcast that can co-exist with existing NTSC**
- **Design a digital transmission system with adequate capacity, robustness, and coverage area for HDTV**
- **Increase the data rate that can be transmitted in a 6 MHz terrestrial broadcast channel to >30 Mbps**
- **Obtain satisfactory data compression at less than 0.5 bits/pixel**
- **Meet the FCC timetable with an “acceptable” demo**

Strategic Challenges

- **Understanding the FCC's (unofficial) view of the significance of other delivery media**
  - **fiber and cable**
  - **tape and other mass storage media**
  - **is terrestrial broadcast their *only* concern?**

- **Evaluating our competition**
  - **Zenith**
  - **CLI, Qualcomm, Teletra, et al**

- **Specsmanship (resolution, S/N, etc.):**
  - **Equal to Zenith?**
  - **Must HDTV have 1000 lines?**
  - **How many points do we get for being *digital*?**

- **Determine what level of demonstration we need:**
  - **Hardware modem and simulations of compression**
    - **(our current program)**
  - **A full real-time hardware system**
  - **Modem transmission of compressed data with non-real-time decompression**

Real-Time FCC Hardware

- **A full real-time system requires an immediate start and an aggressive schedule. Possible approaches are probably limited to:**
  - **Hannover's DCT with block-match motion**
  - **Sarnoff's current MC-QMF approach**

- **Issues**
  - **Insufficient time for innovation**
  - **Program cost and schedule**
  - **May only achieve moderate picture quality**
  - **Effects of channel errors are unknown**
  - **Does Zenith win?**

A Plan for FCC Demonstrations

- **Demonstrate hardware for digital RF transmission**

- **Show simulations of data compression**

- **Demonstrate overall system performance:**
  - **store results of non-real-time compression**
  - **transmit compressed bit stream over the channel**
  - **capture received bit stream**
  - **decompress in non-real-time and display results**

- **Can others help us?**
  - **simulation**
  - **hardware**

Digital RF Transmission

<u>RF Transmission</u>

- **In order for every broadcaster to obtain a simulcast channel, co-channel spacing must be greatly reduced**
  - may not be feasible
  - FCC has been advised that it will work

- **Digital simulcast signals must not interfere with the existing NTSC station, therefore they must be lower power**

- **This means that the existing NTSC is a high-power interference to the digital simulcast channel**

- **There are complex tradeoffs to be made among:**
  - **Power**
  - **Coverage area**
  - **Modulation technique**
  - **Interference characteristics**
  - **Data rate**
  - **Bit error rate and characteristics**
  - **Receiver complexity and cost**

Transmission System Issues

- Will the FCC change their “mode of operation”?
  - will they relax the current blanket rules and allow local solutions?
  - will they consider cellular approaches?

- Is it *really* necessary to provide every current broadcaster with an HDTV channel?
  - the biggest problem is the few top markets
  - e.g., Los Angeles currently has 25 channels

- It appears possible to double the number of channels received by half of the U.S. population
  - they receive less than 10 of the 68 channels

- By relaxing one taboo rule, every household in the U.S. could theoretically receive 28 channels

- Is reduced HDTV broadcast coverage supplemented by cable a solution for the top markets?

- Directional antennas and fill-in slave stations are tools to achieve local solutions for broadcast

Transmission Options

- QAM
  - 64 QAM results in 30 Mbps
  - modified QAM approaches may increase robustness

- Multiple carrier techniques
  - 512/1024 OFDM (LEREA Rennes)
  - 8/16 carriers may allow spectral shaping to reduce interference with NTSC (K. Jonnalagadda)

- Hybrid approaches

Technical Approach

- Sarnoff selected QAM as a good tradeoff having resonable performance and low cost

- Currently working on high-speed hardware for 16/64/256 QAM (to send 20, 30, or 40 Mbps)

- Test and deliver completed hardware

- Current status
  - basic transmitter and receiver completed
  - adaptive equalizer completed
  - current effort focused on clock recovery

Issues

- How to determine the right tradeoffs for digital RF transmission
- Examine advanced signal processing techniques for modem decoding
- Examine other approaches, especially those that accomodate spectral shaping to reduce interference
- Cost
- Adequate testing

Data Compression

Data Compression

- **Digital HDTV has a high data rate:**
  - 1 Mpix/frame x 60 fps = 60 Mpix/sec (just for Y)
- **Transmission in a 6 MHz channel (20-30 Mbps) requires compression to less than 0.5 bits/pixel**
- **Several compression techniques produce good quality at >1bit/pixel**
- **True HDTV quality has not yet been demonstrated at rates below 1bit/pixel**
- **Digital Hierarchy concept further requires transcodability for delivery over other channels**

Data Compression Options

- DCT/block-match motion and frame drop (Hannover)
  - practical hardware with current technology
  - DCT is the JPEG/MPEG path
  - can this achieve HDTV quality below 1 bpp?

- Motion-compensated QMF (current Sarnoff effort)
  - flow-fields are a powerful concept to exploit temporal domain
  - can we extend our motion concepts to apply over more than two frames?
  - how does this relate to 3-D QMF and DCT?

- 3-D Vector Quantization (no effort)
  - information theory says this should be best
  - simple hardware in the receiver
  - how to perform 3-D mapping of vectors?
  - can a satisfactory codebook be designed?
  - how will it look?

Technical Approach

- **Motion-compensated QMF selected because it is a promising approach and it leverages other motion work**

- **Showed that transcodability can be achieved without significant impact on picture quality**
  - Demonstrated simulations at 20, 70, and 140 Mbps

- **Current status**
  - recent results show that just sending flow-field data (no residue) is much better than frame drop
  - this "residue frame drop" is a useful concept
  - simulations using this approach are starting to produce good results at 0.5 bpp (roughly 30 Mbps)

- **Plans**
  - extend motion encoding approach to more frames
  - develop system-level simulation software suite that models buffering, buffer management, error correcting codes, models channel errors, etc.
  - examine the demands of "typical" programming

Discussion

Program Plan

- Continue data compression work
  - expand scope to examine related approaches
  - obtain additional source material
  - follow technology developments and competition
  - collaborate where appropriate

- Continue RF modem work
  - complete QAM modem
  - obtain a copy of OFDM modem from LEREA Rennes

- Should perform more elaborate RF testing
  - test and compare QAM and OFDM
  - is there an in-between approach that makes sense?

- Should address lower-level system design
  - error management strategy and robustness
  - integrated approach to source and channel coding
  - sync, audio, and video budgets and error strategy
  - extend hierarchy concept to audio, signal formats, error correcting codes, etc.

<u>Program Plan, cont'd</u>

- **Should address RF system issues**
  - **our weakness compared to Zenith**
  - **need to better understand interference issues**
  - **need to develop a "frequency allocation" plan that is politically acceptable**

- **Should address "specsmanship" issues**
  - **what are the *real* criteria of the FCC?**
  - **what is our competion claiming?**
  - **what can our competion deliver?**

- **Should begin to develop a system for FCC demos**
  - **computer-to-tape interface (to generate bits)**
  - **tape-to-modem interface (to send the bits)**
  - **modem-to-tape interface (to capture the bits)**
  - **tape-to-computer interface (to decompress)**